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FC Cincinnati Stadium

Review of Akustiks April 9th Report  
for Music Hall

Draft 1 | April 30, 2019

Draft

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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**ARUP**

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# 1 Introduction

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Arup has been engaged to conduct a review of Akustiks' April 9, 2019 report, titled *FC Cincinnati Stadium Environmental Noise Model*.

Arup's prior experience includes projects for concert hall operators to evaluate environmental noise impact from adjacent entertainment venues (e.g., recently for Meyerson Symphony Center in Dallas) and projects for sporting venue operators (e.g., recently for the Golden State Warriors' new arena).

In this report, we review Akustiks' sound emission predictive study from the new FC Cincinnati Stadium to spaces within Cincinnati Music Hall.

Akustiks' report follows a standard format for environmental noise studies by evaluating (1) the sound source; (2) the path for sound transmission; and (3) the environment of the listener / receiver.

This report considers Akustiks' analysis within the broader environmental noise context at Music Hall during performances, and assesses the probability of the scenarios described in Akustiks' report. Further, this report summarizes both (a) where we are in general agreement with the analysis provided by Akustiks and (b) where we have additional comments and/or propose that other analyses be considered.

## 2 Executive Summary

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- A. The impact of exterior noise on activities within Cincinnati Music Hall is a function of:
- i. Sound isolation performance of the building envelope;
  - ii. Level of residual background noise in the performance space during those activities;
  - iii. The loudness, duration, and tonal quality of incoming noises, as well as how often those noises occur.
- B. Cincinnati Music Hall underwent a significant renovation from 2016 to 2017. Despite the low sound isolation performance of the building (outdoor sirens are clearly audible in Springer Auditorium), the exterior building envelope of Music Hall was not modified during this renovation.
- C. The residual background noise level inside Springer Auditorium during a performance was not analyzed by Akustiks, but is significant to this study.
- i. Akustiks reports that after renovation, the unoccupied the background noise level in Springer Auditorium (due to only building mechanical systems operation) was brought down approximately to Noise Criteria (NC) 12. Arup's measurements taken at the rear lighting bridge in Springer Auditorium measured between NC 13 and NC 15, which indicates that the acousticians are, within reasonable variation, in general agreement regarding the unoccupied sound levels in the Auditorium.
  - ii. Background noise levels in Springer Auditorium, which accommodates over 2000 patrons, will be higher when the auditorium is occupied for performances.
  - iii. Recently published research indicates that occupied sound levels in concert halls are at least 5 dB higher than when unoccupied.<sup>1</sup> Arup has not taken acoustic measurements in Springer Auditorium during performances, but such data, if available, would be useful in the analysis of this matter.
  - iv. We estimate the residual lowest background noise level during a performance would be NC 17 or higher, and more than 99% of a typical performance will be at least another 5 dB (or 5 NC points) above this level.
- D. Peak crowd noise described in the Akustiks report occurs for very short durations and very infrequently, primarily during attempts on goal.

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<sup>1</sup> JASA 131(4):2753-61.

- i. Based on data taken by Arup during three professional soccer matches in stadia ranging from 22,500 to 54,000 seats, peak noise levels generally last for less than 4 seconds and occur less than 4% of the match.
  - ii. Moreover, average crowd noise levels are at least 10 dB below peak noise levels. Based on peak crowd noise levels calculated by Akustiks, average crowd noise will be at or below even unoccupied background sound levels in Springer Auditorium - and will therefore be inaudible in Springer Auditorium when it is occupied by patrons.
- E. Overlap of peak crowd noise and a fermata (quiet or hushed pause) moment during an event at Music Hall is an extremely low probability:
  - i. There are 17 regular season matches in the MLS season, not including exhibition matches and possible playoff matches.
  - ii. During the current MLS season and the concert season published by Music Hall from January to the end of June of 2019, a soccer match and concert occur simultaneously only three times (March 30, 2019, April 7, 2019, and May 25, 2019). This overlap of simultaneous events occurs even without coordination between the parties designed to reduce such overlap.
  - iii. Arup measured sound levels during a 2014 performance of the Minnesota Orchestra at newly renovated Northrop Auditorium, which is a similar era of concert hall and building with unoccupied background noise levels of NC 15. Over the entire performance, there were six total moments in the concert where a fermata occurred within 5 dB above the occupied background noise level. The total duration of these moments was 0.34% of the concert (or approximately 26 seconds of a 2-hour performance).
  - iv. Given (a) the infrequent overlap of soccer matches and Music Hall performances; (b) the short duration of the peak crowd noise levels referenced in Akustiks' analysis; and (c) the infrequent moments of hushed pauses in a performance, the probability that peak crowd events will occur simultaneously with a quiet passage in a musical performance is extremely low.
- F. Based on Akustiks' crowd noise predictions, even if the very unlikely overlap scenario occurs, the patron experience will be minimally affected (if at all) because:
  - i. Peak crowd noise ingress (per Akustiks' reported calculations) will be less than 7 dB above the residual background sound in the hall, and less than 2 dB above the lowest sound level during more than 99% of a typical performance.

- ii. At the distance between Music Hall and the Stadium, the quality and character of crowd noise from the Stadium is a relatively neutral sound, similar to high wind noise, general moving traffic, and other “broadband” environmental sounds. This sound is not discernable in a manner similar to “tonal” sounds, such as sirens, helicopters, or shouting that occurs immediately outside a building where distinct voices can be heard. Broadband crowd noise ingress will be generally indistinguishable among more obvious sounds in the hall (e.g., people coughing, shuffling programs, noise from adjacent spaces and immediately outside the venue).
- G. In the context of the urban environment around Music Hall, there are tonal sounds (sirens) that are louder, occur with greater frequency and have a longer duration than the peak crowd noise levels predicted by Akustiks.
- i. To document the outdoor environment, Arup conducted site measurements for a week-long period (April 10 to 17), logging continuous sound levels on the roof of Music Hall. Our results show that on a daily basis, there are many outdoor noise events which are louder than the 77 dBA peak crowd noise levels predicted by Akustiks.
  - ii. In particular, sirens are a more regular source of outdoor noise that is louder and last longer than Akustiks’ prediction of peak crowd noise levels. Further, sirens are tonal in quality, which makes them distinctly more audible in Springer Hall, and therefore more impactful.
  - iii. Although sirens are more likely to occur during a performance, Music Hall did not upgrade its building envelope sound isolation due to siren noise intrusion.
- H. In summary, considering the crowd noise predictions from Akustiks’ April 9, 2019 report within the site and usage context, Arup does not expect crowd noise to have any discernable impact on the operations or patron experience in Springer Auditorium or Music Hall in general.

## 3 Technical Review

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### 3.1 Sound Source

Akustiks identifies the following sound sources in the new Stadium as the basis for their study:

- (a) Crowd noise during a soccer match
- (b) PA system during a soccer match
- (c) Amplified sound during a concert event
- (d) Pyrotechnics

#### **Sound Source Scenario - Crowd Noise during a Soccer Match**

Akustiks' report provides their methodology for sound source calculations, which is based on a 3D model of the new Stadium and surrounding site and buildings, constructed using the software program SoundPLAN®. The sound source for crowd noise was calculated by applying a uniform sound-power-per-unit-area over the seated portion of the Stadium bowl, and calibrated in order to achieve sound pressure levels on the field of approximately 105 dBA. While not specifically stated, we assume Akustiks used a "conformal area" source type. In the frequency domain, the source sound levels were adjusted spectrally to match a common reference for "shouting" for the male human voice. This model is intended to represent only the absolute peak levels produced by the crowd during a match.

- Noise mappings from Akustiks' SoundPLAN model show that the sound pressure levels in the seated areas exceed 110 dBA when they run the simulation as described in their report, however the specific highest peak levels in the seated area are not reported by Akustiks.
- Arup has data from measurements taken within the stands during Premier League games in the UK. Upon review, we agree that sound pressure levels during peak events will on occasion exceed 110 dBA, and therefore generally agree on the source sound level modeling used in Akustiks' report. However, we make the following clarifications:
  - In three Premier League matches which Arup analyzed, we continuously took one-minute measurements throughout the game. In all three instances, we found that instantaneous peak sound levels exceeded 110 dBA in the seated areas within only 3 to 4% of our one-minute measurements during each match. See Figures 1a through 1c.

- Within each 1-minute long measurement, no single event generated instantaneous peak levels which exceeded 110 dBA for longer than 3.6 seconds. Samples from the highest peaks in each match are shown in figures 2a through 2f.

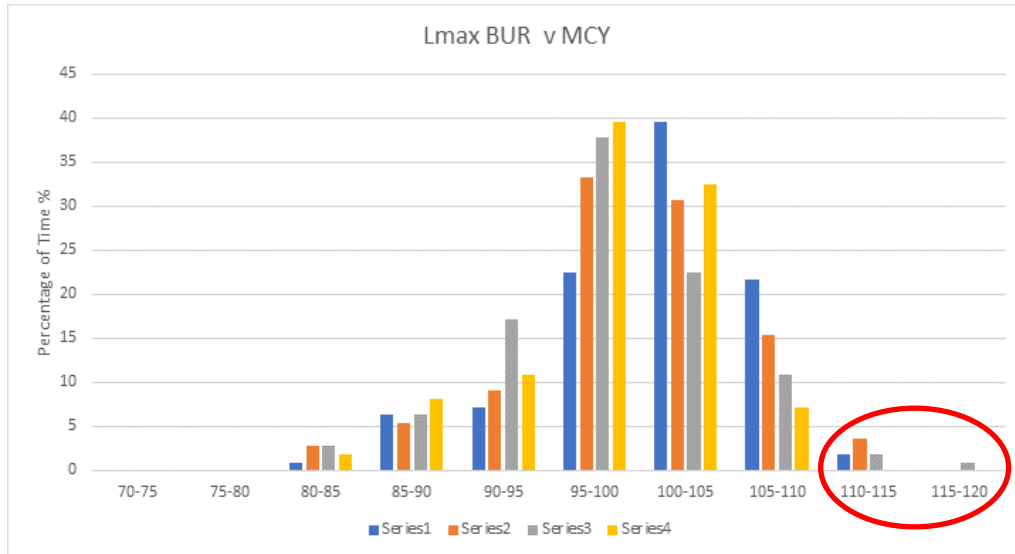


Fig 1a: Categorization of maximum sound levels during 1-minute sound measurements at Burnley v Manchester City 1-0, 14 March 2015

Stadium: *Turf Moor*; seat capacity 22,546

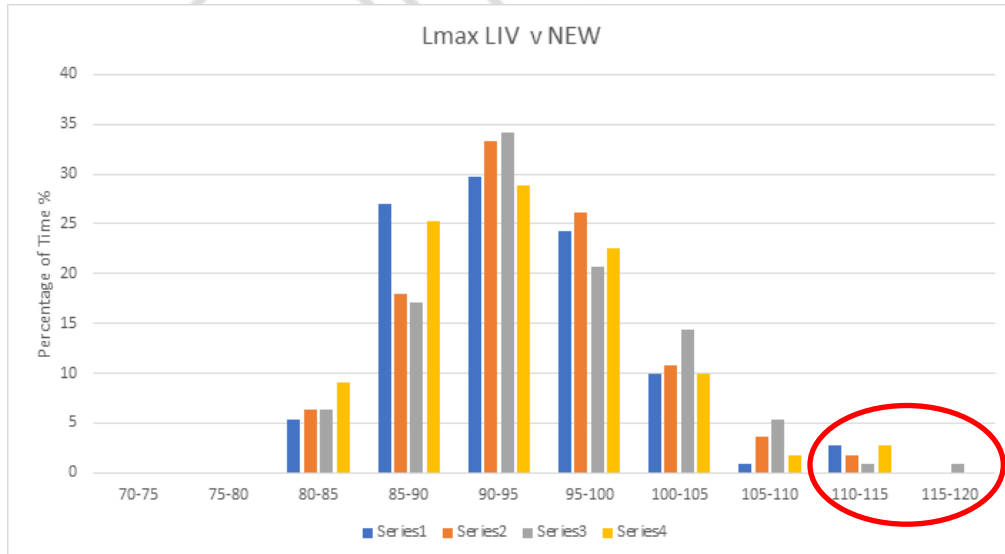


Fig 1b: Categorization of maximum sound levels during 1-minute sound measurements at Liverpool v Newcastle 2-0, 13 April 2015

Stadium: *Anfield*; seat capacity 54,074

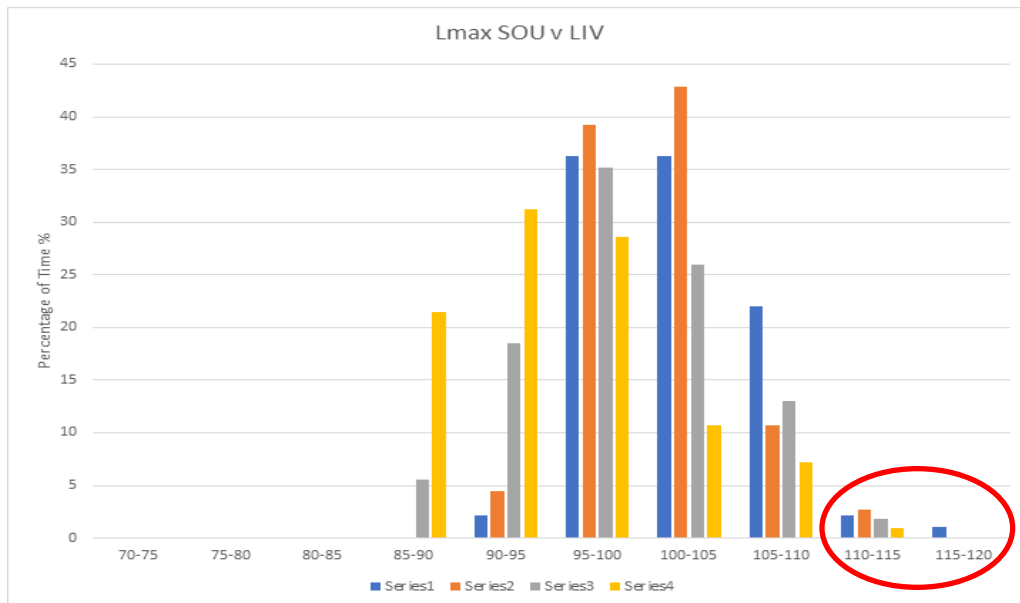


Fig 1c: Categorization of maximum sound levels during 1-minute sound measurements at Southampton v Liverpool 0-2, 22 February 2015

Stadium: St. Mary's; seat capacity 32,505

## Burnley vs. Manchester City, 14<sup>th</sup> March, Turf Moore

Jimmy McIlroy Stand – Middle,  $L_{max, 1min}$ : 116 dBA,  $L_{eq, 1min}$ : 103dBA

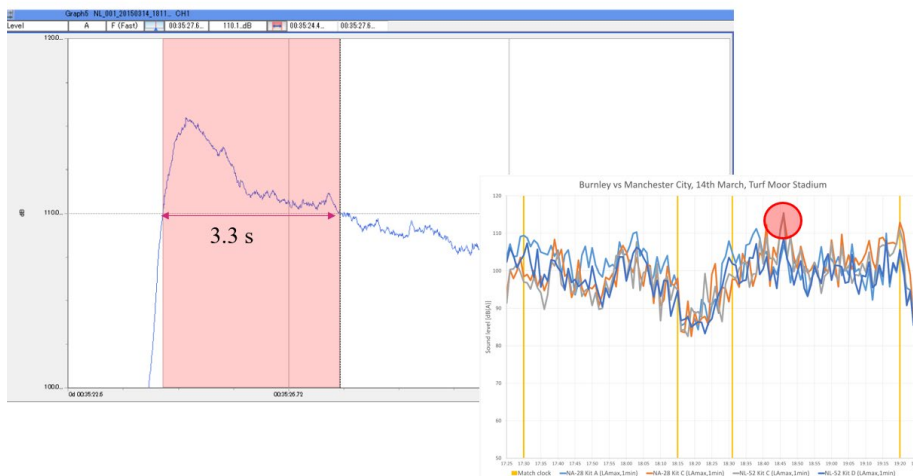


Fig 2a: Time envelope of sound levels exceeding 110 dBA for selected peak crowd noise moment during the referenced match

Stadium: St. Mary's; seat capacity 32,505

## Burnley vs. Manchester City, 14<sup>th</sup> March, Turf Moor

Jimmy McIlroy Stand – Middle,  $L_{\max, 1\text{min}}$ : 113 dBA,  $L_{\text{eq}, 1\text{min}}$ : 102 dBA

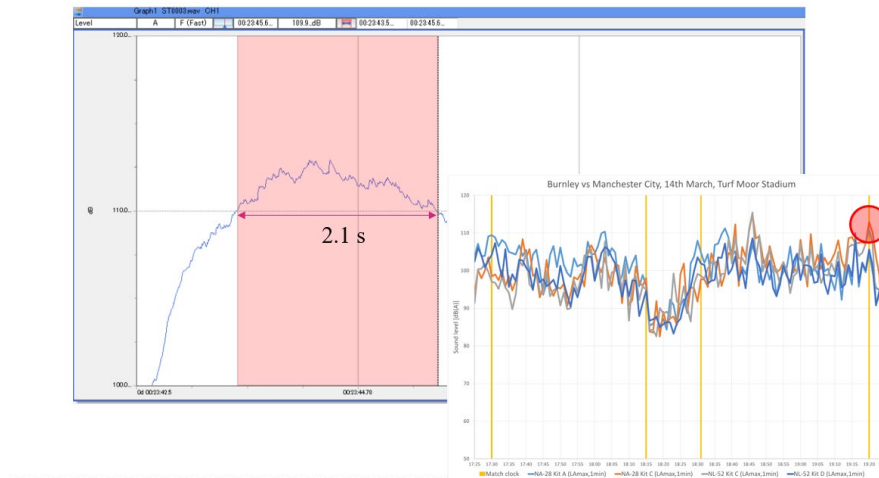


Fig 2b: Time envelope of sound levels exceeding 110 dBA for selected peak crowd noise moment during the referenced match

## Liverpool vs. Newcastle, 13<sup>th</sup> April, Anfield

Main Stand,  $L_{\max, 1\text{min}}$ : 116 dBA,  $L_{\text{eq}, 1\text{min}}$ : 101 dBA

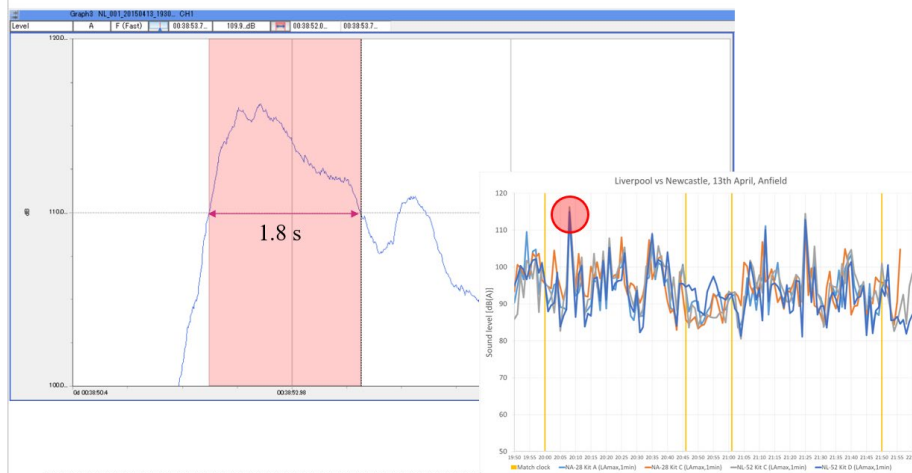


Fig 2c: Time envelope of sound levels exceeding 110 dBA for selected peak crowd noise moment during the referenced match

## Liverpool vs. Newcastle, 13<sup>th</sup> April, Anfield

Main Stand,  $L_{\max, 1\min}$ : 115 dBA,  $L_{\text{eq}, 1\min}$ : 98 dBA

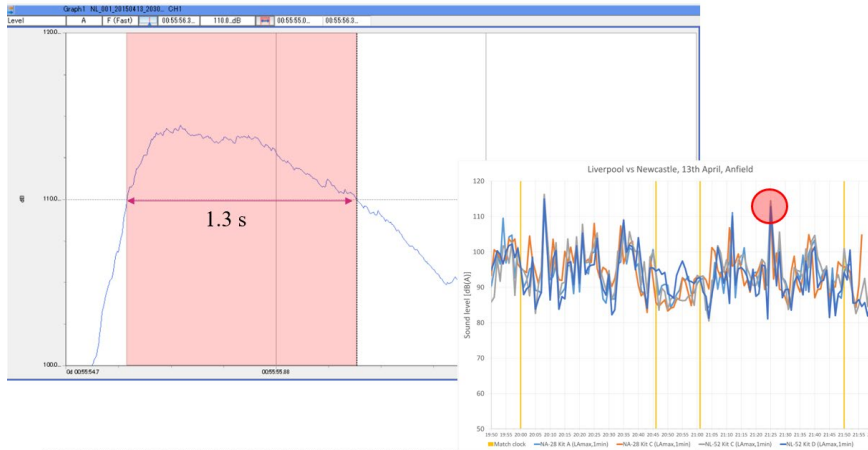


Fig 2d: Time envelope of sound levels exceeding 110 dBA for selected peak crowd noise moment during the referenced match

## Southampton vs. Liverpool, 22<sup>nd</sup> February, St Mary's Stadium

North Stand-Top,  $L_{\max, 1\min}$ : 114 dBA,  $L_{\text{eq}, 1\min}$ : 102 dBA

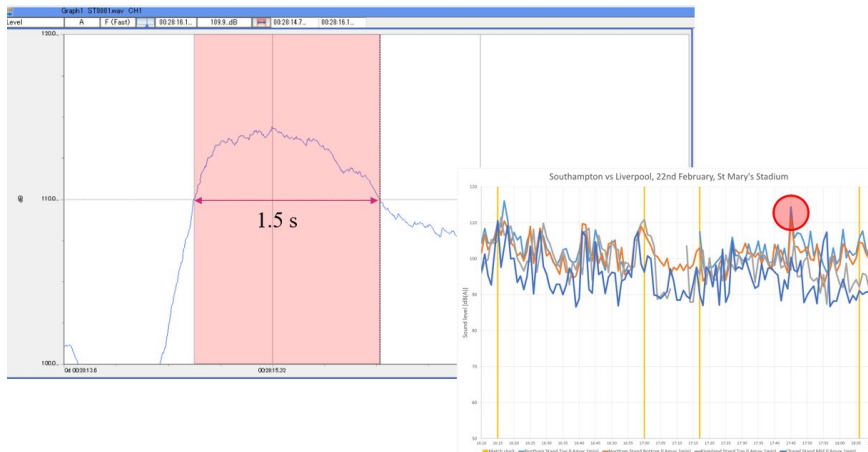


Fig 2e: Time envelope of sound levels exceeding 110 dBA for selected peak crowd noise moment during the referenced match

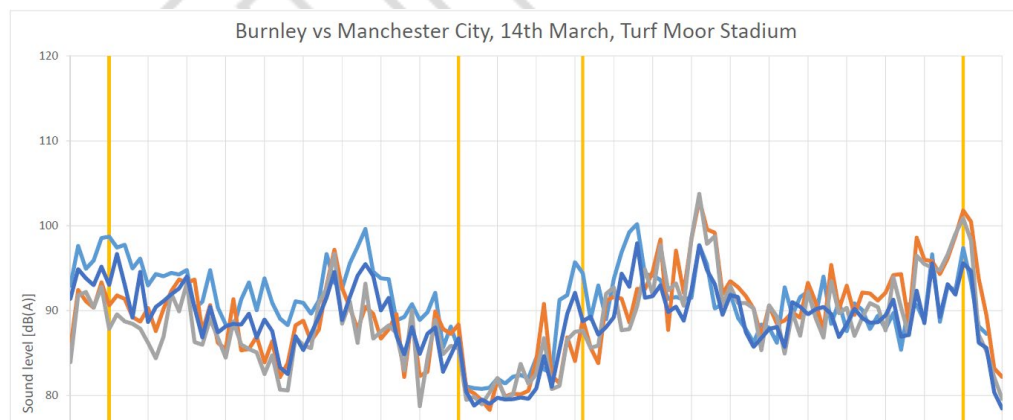
### Southampton vs. Liverpool, 22<sup>nd</sup> February, St Mary's Stadium

Northam Stand-Top,  $L_{\max, 1\min}$ : 116 dBA,  $L_{eq, 1\min}$ : 102 dBA



Fig 2f: Time envelope of sound levels exceeding 110 dBA for selected peak crowd noise moment during the referenced match

- After these instantaneous peaks occur, crowd noise trends back to the average sound levels sustained over the course of the match. Equivalent average sound levels ( $L_{eq}$ ) sustained by the crowd during these matches were at least 10 dBA less than peak levels, as seen in Figures 3a and 3b.



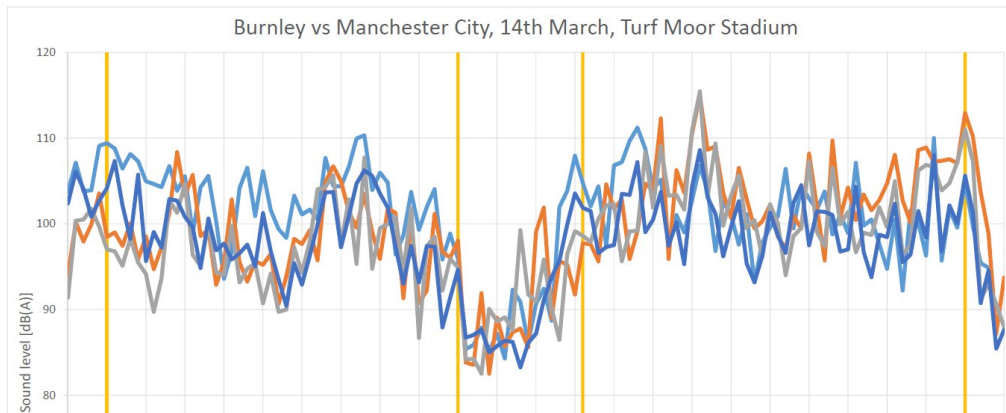


Fig 3a and 3b: Yellow vertical lines indicate match start, halftime and end of match. Graphed data represents measurements in four different locations around the seating bowl. As shown, peak levels (lower graph) are 10 dB or higher above average levels (upper graph).

### Sound Source Scenario - PA system during a soccer match

The PA system has not been fully designed at this time. However, based on *50% Design Development* drawings of the new Stadium (dated February 1, 2019) the full perimeter canopy design allows for all primary PA loudspeakers to be downward-facing and hung from the underside of the canopy. Additional smaller infill loudspeakers will serve areas obstructed from the main PA system. This approach is expected to support compliance with Municipal Code Section 909-3, which in turn would ensure that use of the PA system during matches would not have any audible impact within Music Hall. The PA system sound source is therefore not addressed in this report.

### Sound Source Scenario - Amplified sound during a concert event

When the Stadium is used as an entertainment venue for concerts and other events, FC Cincinnati will have to apply for a Special Events Permit, which is governed by Municipal Code Section 765. If electronically amplified music will be played at an event, the applicant must also submit “an appropriate plan for the control of sound” as part of its application. This process is specific to each requested Special Event Permit. As such, if concert event sound levels or mitigation are to be addressed, it will be a matter of the permitting process and is not addressed in this report.

### Sound Source Scenario – Pyrotechnics

Similar to the concert event scenario, we understand that any pyrotechnics will need to be permitted, and therefore pyrotechnics are not addressed in this report.

## 3.2 Sound Transmission Path

There are two sound transmission paths assessed in the Akustiks report:

### **Sound Transmission Path 1 - Stadium to Music Hall façade/roof**

Akustiks' report states that the transmission path for sound generated from within the new Stadium to the exterior envelope of the Music Hall building is calculated by SoundPLAN. We are aware that SoundPLAN uses ISO standard calculation methods and we take no exception to this portion of the study.

### **Sound Transmission Path 2 - Music Hall façade/roof to interior locations within Music Hall**

We understand that Akustiks estimated the level of noise reduction from the exterior envelope of Music Hall to the receiver locations within the building by conducting simultaneous noise level measurements on the upper building roof and within Music Hall while firing a shotgun from a lower roof area approximately 30 feet away from the rooftop microphone.

This is not a standard means of measuring noise reduction through a building material, and it is unclear how repeatable this result would be if conducted multiple times. However, Arup acknowledges it is difficult to devise a site measurement protocol that will represent the exact noise reduction from a sound source at the distance of the Stadium.

## 3.3 Site Environmental Noise Context

Akustiks' report provides predictions of the outdoor sound levels at the roof of Music Hall due to instantaneous peak crowd events. However, their report does not include the contribution of other sources of environmental noise in the area. The peak crowd noise level at the roof as predicted by Akustiks is 77 dBA.

From April 10 to April 17, 2019, Arup conducted attended and unattended continuous measurements on the roof of Music Hall (see Appendix). During these seven days, we captured many discrete events from common sources which were as loud or louder than the predicted level of peak crowd noise (77 dBA) from the Stadium.

Of all the outdoor noise sources we measured from the roof of Music Hall, the most significant exceedances were from sirens, some of which were as much as 15 dBA above Akustiks' predictions of the new Stadium peak crowd levels.

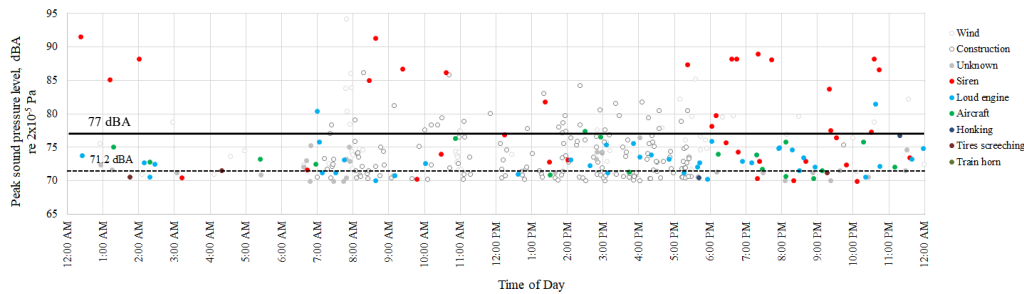


Figure 4 – Aggregate of one week of measurements on Music Hall roof, conducted from April 10 to 17<sup>th</sup>. Solid line represents peak crowd noise predictions from the Akustiks report. Dashed line represents the same with a 6 dB “tonal noise” penalty applied.

Moreover, sirens were clearly audible inside an unoccupied Springer Auditorium while Arup was conducting testing. Although many other sources – including construction noise – exceeded 77 dBA while Arup was inside Springer Auditorium, we found that, except for sirens, it was impossible to discern if faint sounds were coming from inside or outside the building.

### Noise Quality

Sirens are much more discernable than crowd noise. Crowd noise, at a distance, is made up of the accumulation of human voices which contain energy in a broad range along the audible frequencies of sound. This is called “broadband” sound and it is similar to white noise, or the sound of air or water rushing.

Conversely, a siren is considered a “tonal” noise. It is, by design, intended and able to cut through background sound much more distinctly. A tonal sound needs to be much quieter than a broadband sound in order to be equivalent in perceived loudness. To this point, highly tonal sounds are usually penalized by 6 dB in environmental noise studies.<sup>2</sup> For this reason, the scatter plots from our seven days of site testing on Music Hall (see Appendix) compare sound levels to both 77 dB (peak crowd noise predictions from Akustiks) and 71 dBA (the same with 6 dB “tonal noise” penalty applied).

### Noise Duration

Figures 2a through 2f in this report demonstrate that peak crowd noise from the Stadium will generally last less than 4 seconds in duration. However, our rooftop measurements at Music Hall found sirens can last longer depending on the number of emergency vehicles. Sample siren durations taken during our survey were found to exceed both 71 dBA and 77 dBA levels for 10 to 38 seconds (see Figure 5). As such, these siren events last significantly longer than the crowd noise peaks described in the Akustiks report.

<sup>2</sup> See ISO standard 1996.

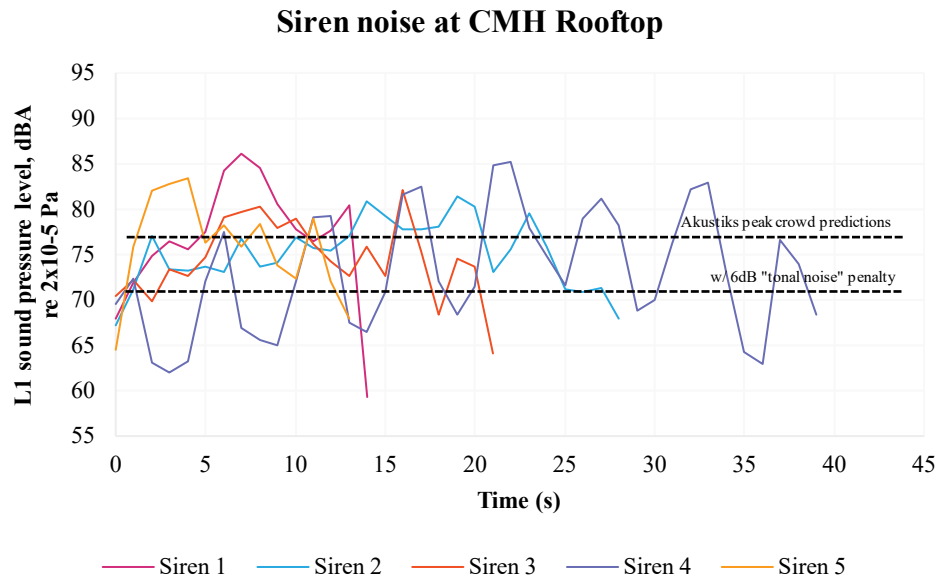


Figure 5 – Sampling of five siren events measured by Arup on Music Hall roof.

### 3.4 Listener / Receiver Context

Within Springer Auditorium, Akustiks notes that unoccupied background sound levels are very low, which was an intentional design outcome from the recent renovation. Such low background sound levels in a concert hall are often considered to benefit patrons by increasing the dynamic range of audible music within a concert hall. Akustiks' report compares predictions of noise ingress from peak crowd events at the new Stadium to the level of background noise measured in an unoccupied hall. However, studies show that once a hall is filled with musicians and patrons, the background sound level inevitably increases, even if patrons are simply quietly sitting in their seats. Recent studies show that background sound levels during performances were between 5 and 13 dB higher than the unoccupied background sound level.<sup>3</sup>

#### Duration and Level of Sound During Pauses in Performances

Arup does not have access to any measurements during sample performances at Music Hall. However, we do have recordings and measurements from a 2014 performance of the Minnesota Orchestra taken at Northrop Auditorium, which has an unoccupied background noise level of NC 15.

- Over the entire performance, there were six total moments in the concert where fermata (pauses) occurred and approached within 5 dB of the occupied background noise level.

<sup>3</sup> JASA 131(4):2753-61.

- Moreover, over the course of the performance, the sound level was more than 5 dB above background sound 99.66% of the time.
- As such, because the total duration of these hushed pauses was only 0.34% of the concert, and because the peak sound levels during a soccer match generally last for less than 4 seconds and occur less than 4 percent of the match, it is very unlikely that peak crowd noise would have an intrusive effect on a Music Hall event.

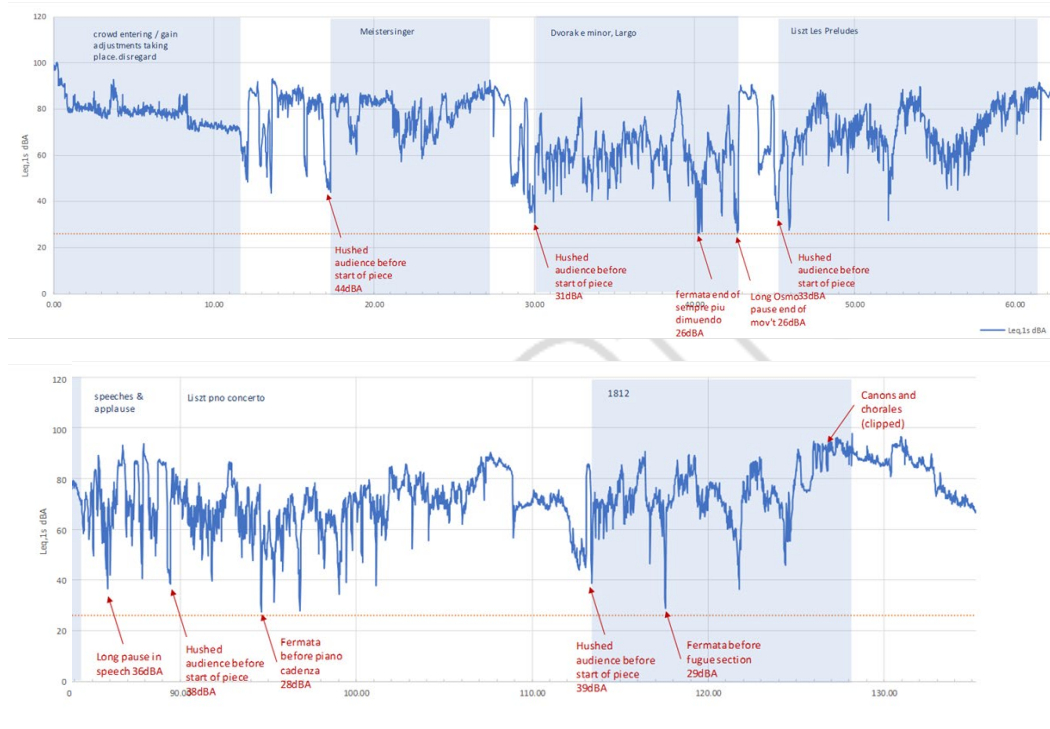


Figure 8 – Sound Levels during Minnesota Orchestra performance at Northrop Auditorium, 2014.

## 4 Conclusion

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When expanding the analysis conducted by Akustiks to include the site noise context and temporal context of events and performances, we conclude it is highly unlikely that peak crowd noise events from the new Stadium will have an impact on the enjoyment of Music Hall performances. The reasons are:

- a) While Akustiks predicts peak crowd noise events to be up to 12 dB above the unoccupied hall background noise, recent studies establish that the quietest occupied levels in the hall will be at least 5 dB higher, and comparable data measured by Arup shows it will be at least 10 dB higher over 99% of the time. This increased background sound level should be the basis for any analysis of the patron experience in Springer Auditorium.
- b) Based on data taken at professional soccer matches, peak crowd noise events occur for less than 4 seconds in duration, then tail off towards average crowd noise levels which are at least 10 dB lower than peak levels. Average crowd noise during a match will be at or below the unoccupied background noise levels in Springer Auditorium and will therefore be inaudible in Springer Auditorium when occupied by patrons.
- c) From January to June 2019, soccer matches and Music Hall events occur in overlapping timeframes only three times. Moreover, this scheduling overlap occurred *without* the parties working to avoid such an overlap.
- d) Though Arup is unsure of the accuracy of Akustiks' calculation for outdoor to indoor noise reduction for Music Hall., everyday urban noises – particularly sirens – often significantly exceed the level and duration of Akustiks' predicted level of crowd noise from the future Stadium.
- e) As opposed to the broadband quality of crowd noise from a distance, sirens create a sharp tonal noise. Even though other outside sources (such as construction noise) exceeded the predicted level of peak crowd noise reaching Music Hall, sirens were the only outdoor noise source clearly identifiable during Arup's site survey within an unoccupied Springer Auditorium. Sirens are an unpredictable daily occurrence throughout the year.
- f) Taking the site environment and event context together, Arup does not believe the peak crowd noise levels predicted in Akustiks' report will be distinguishable in an appreciable manner during Music Hall performances, and the probabilistic likelihood of peak crowd events occurring during hushed pauses is minimal.
- g) As the impact of sirens and other outside noise sources has not necessitated Music Hall's upgrade of the sound isolation of its building envelope, including during the recent renovation, the peak crowd noise levels predicted by Akustiks should not be of concern.

## Appendix A: Arup Site Measurement Overview

Arup conducted an environmental noise survey at the Cincinnati Music Hall (CMH) where we logged outdoor noise levels over the course of a week from Wednesday, April 10 to Wednesday, April 17, 2019. The primary purpose of the survey was to record and measure transient outdoor noise sources on the roof of Music Hall, and to then make direct comparison to the predicted peak crowd noise events from the new Stadium as provided in Akustiks' April 9, 2019 report.

### A1 Measurement Setup

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#### Equipment

Two Brüel and Kjær Noise Sentinel logging kits, serial numbers 2926303 and 3008358, were used to carry out noise logging measurements. Each kit contained a 2250 Sound Level Meter and a Type 4592 Outdoor Microphone with an attached windscreen. The microphones were calibrated prior to beginning the noise logging according to the manufacturer's instructions.

#### Measurement Positions

Logging kit 2926303 was set up at the southeast corner of the north mechanical penthouse roof, with the microphone at a height of 5'11" above the penthouse roof surface, shown in Figure A1. This location was the closest accessible position to the pitched roof over Springer Auditorium with line of sight to West Central Parkway and Ezzard Charles Drive, as shown in Figure A2. The line of sight to West Central Parkway from higher the pitched roof would be less obstructed, while the line of sight to Ezzard Charles Drive would be more obstructed.



Figure A1 – Rooftop logging kit location



Figure A2 - View to the west and north from the rooftop microphone location

Logging kit 3008358 was set up inside Springer Auditorium at the center of the theatrical lighting cove, as shown in

Figure A3. The microphone was located 3' above the floor of the lighting cove, 30' above the floor of the first row of the top balcony level and 44' below the pitched roof directly above. This location was chosen because it was the closest position to the audience inside the auditorium that would not obstruct day-to-day operations.

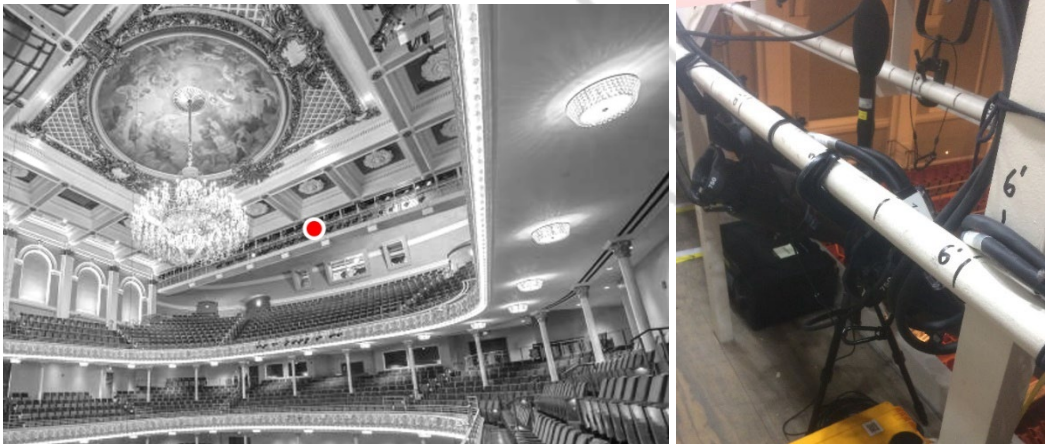


Figure A3 – Springer Auditorium interior logging kit location

## Noise Alerts

The rooftop logging kit was set to trigger an alert if the peak fast time-weighted RMS sound pressure level exceeded 70 dBA during a one-minute interval. The alert level was chosen to be slightly below the 71.2 dBA peak sound pressure level of soccer match crowd noise at the CMH rooftop predicted by Akustiks in their report on p. 36. Each alert consists of the maximum peak sound level measured during the one-minute interval along with a minute-long monaural audio recording.

## A2 Attended Listening

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Two periods of attended listening were carried out in order to visually and aurally identify environmental transient noise sources.

### Period 1

On Wednesday, April 10 from 6:00 PM to 7:00 PM, two Arup consultants, one located at the rooftop measurement location and one at the auditorium interior measurement location, listened for and noted transient noise sources.

At 6:21 PM, a siren was clearly audible above background noise inside the auditorium as well as on the rooftop. No other noise sources were heard at the two positions simultaneously.

### Period 2

On Wednesday, April 17 from 1:00 PM to 8:30 PM, an Arup consultant at the rooftop measurement location listened to and visually observed transient environment noise sources. These observations were used to identify and classify noise sources audible in the noise alert sound recordings made by the rooftop logging kit.

## A3 Logging Analysis

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### Transient Noise Sources

The following transient noise sources were found to exceed the 70 dBA alert threshold:

- Sirens
- Loud engines
- Honking
- Screeching tires
- Aircraft
- Train horn
- Construction activity
- Wind
- Unknown / unidentifiable sources

Over the course of the logging period there were several periods of ongoing construction noise from a road construction site at the intersection of West Central

Parkway and Ezzard Charles Drive, directly adjacent to CMH and visible from the rooftop microphone position. The construction site is shown in Figure A4.



Figure A4 - Construction site at intersection of West Central Parkway and Ezzard Charles Drive

Over the logging period were also intervals of high wind noise. During periods of both construction and wind noise, noises from other sources were audible in alert recordings but are excluded from our final data set due to the difficulty of determining which source triggered the alert during the one-minute measurement interval. Figure A5 summarizes periods of construction noise and wind noise that were identified by listening to the alert audio samples.

Day	Construction Noise	Wind Noise
Wednesday, April 10	None (Logging began after construction hours)	None
Thursday, April 11	8:20 AM to 5:30 PM	None
Friday, April 12	8:00 AM to 8:30 AM, 10:50 AM to 5:00 PM	Occasional gusts
Saturday, April 13	None	None
Sunday, April 14	None	4:10 PM to 11:59 PM
Monday, April 15	8:00 AM to 12:45 PM, 1:50 PM to 5:00 PM	12:00 AM to 8:20 AM
Tuesday, April 16	7:00 AM to 2:00 PM	Occasional gusts
Wednesday, April 17	8:00 AM to 5:40 PM	None

Figure A5 - Observed periods of construction noise and wind noise

### Transient Noise Log

Figure A6 through Figure A13 show the peak A-weighted sound pressure levels of transient noise sources exceeding 70 dBA measured at the rooftop logging location.

The solid black line at 77 dBA represents the peak A-weighted sound pressure level of soccer match crowd noise predicted at the CMH rooftop by Akustiks in their report on p. 36.

The dashed black line represents the same with a 6 dB penalty for “tonal” noises such as sirens.

Figure A14 shows data from the seven days of the logging survey superimposed onto one 24-hour period.

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# Appendix B: Arup Site Measurement Results Summary by Day

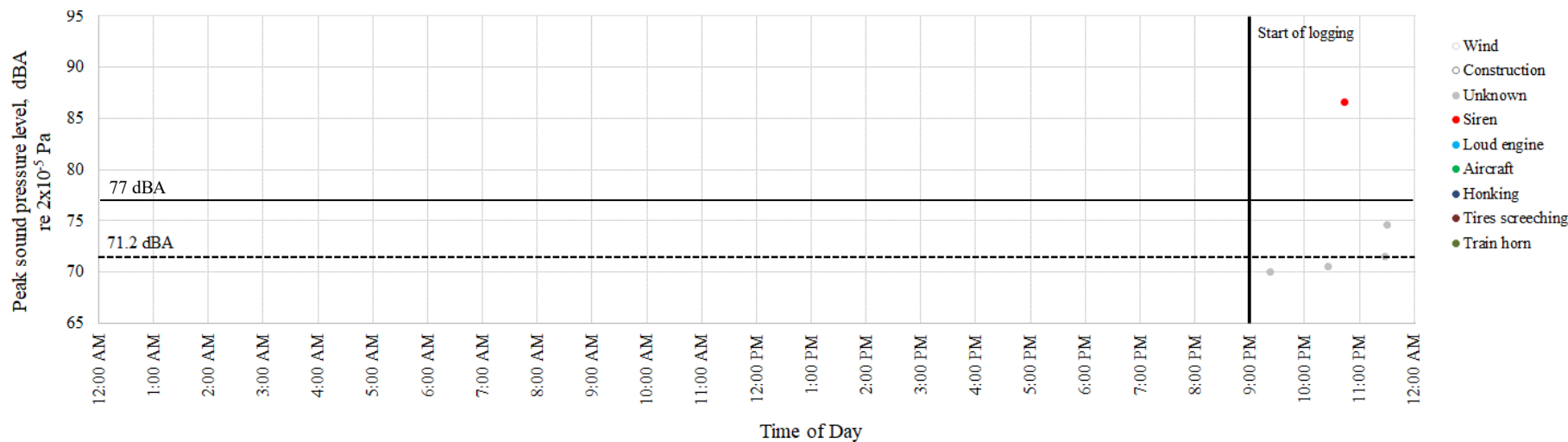


Figure B1 – Transient Noise Log for Wednesday, April 10, 2019

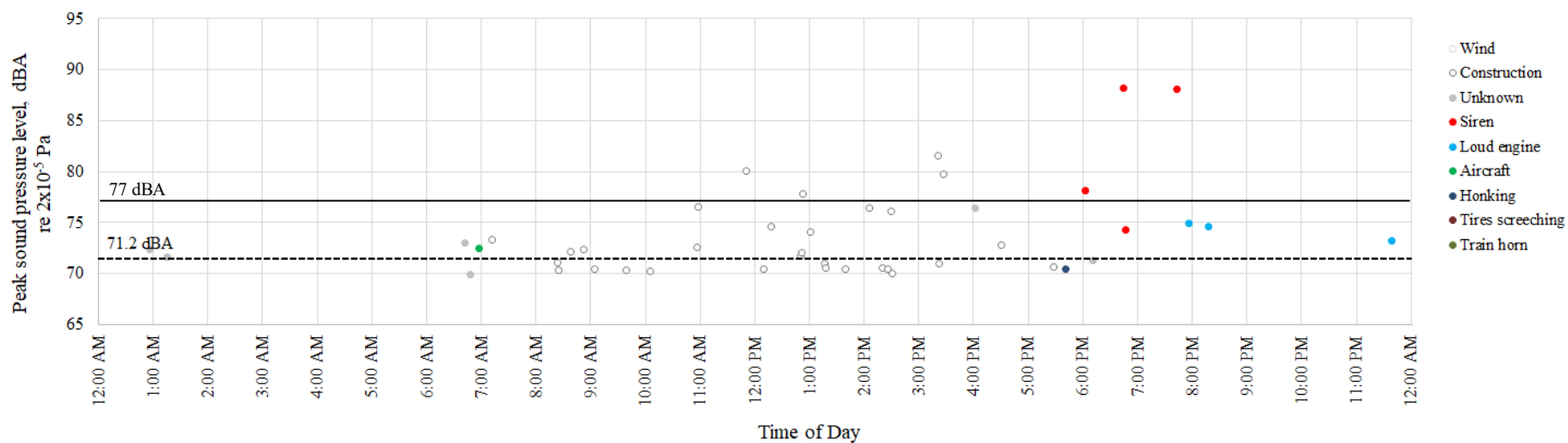


Figure B2 – Transient Noise Log for Thursday, April 11, 2019



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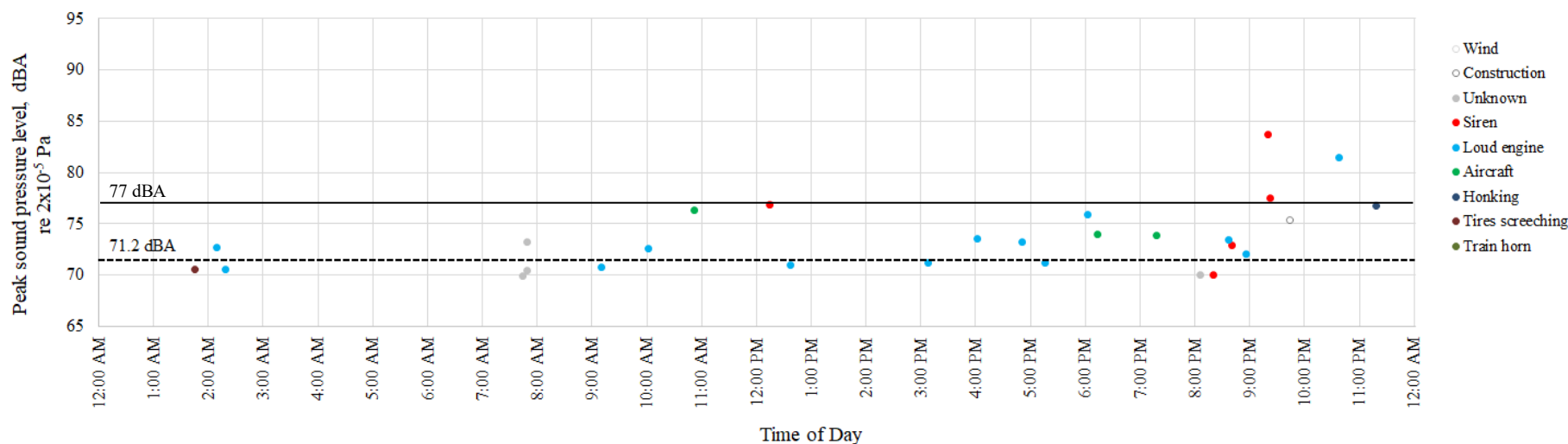


Figure B4 – Transient Noise Log for Saturday, April 13, 2019

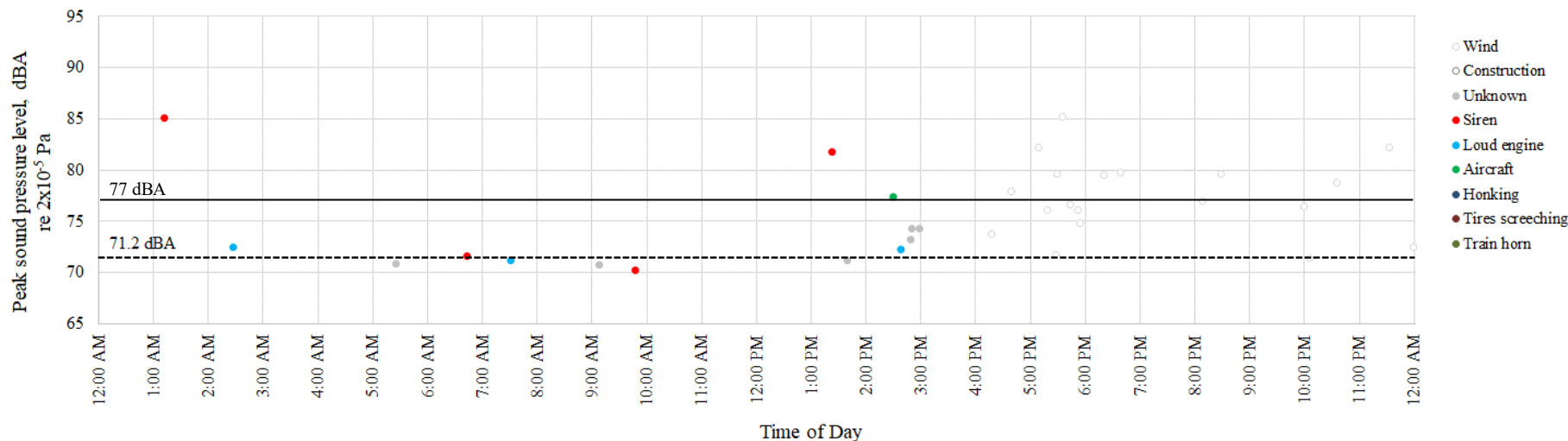


Figure B5 – Transient Noise Log for Sunday, April 14, 2019

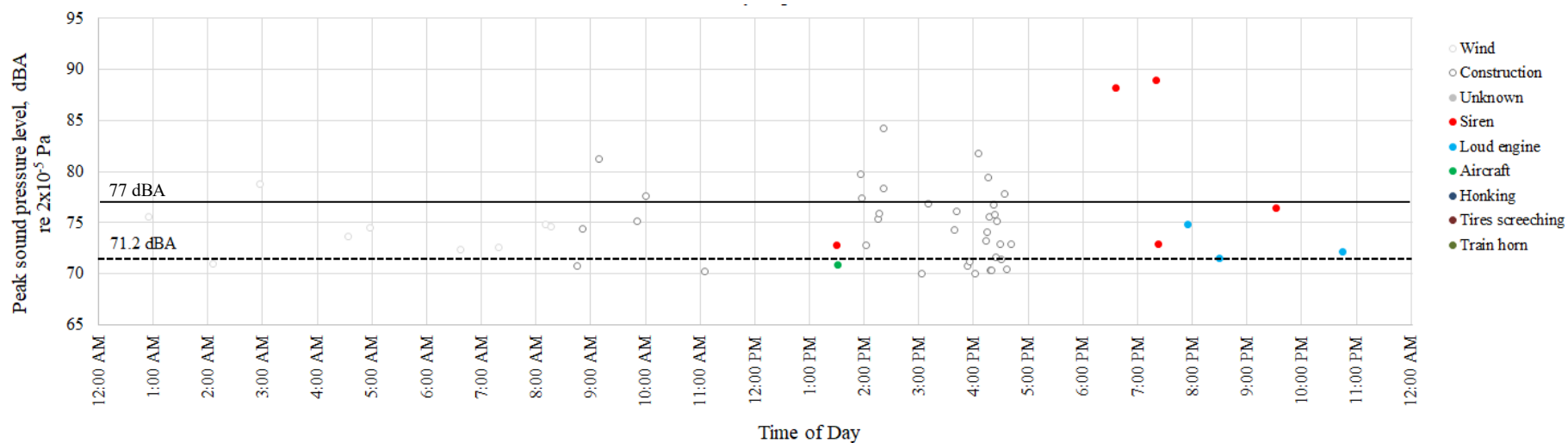


Figure B6 – Transient Noise Log for Monday, April 15, 2019

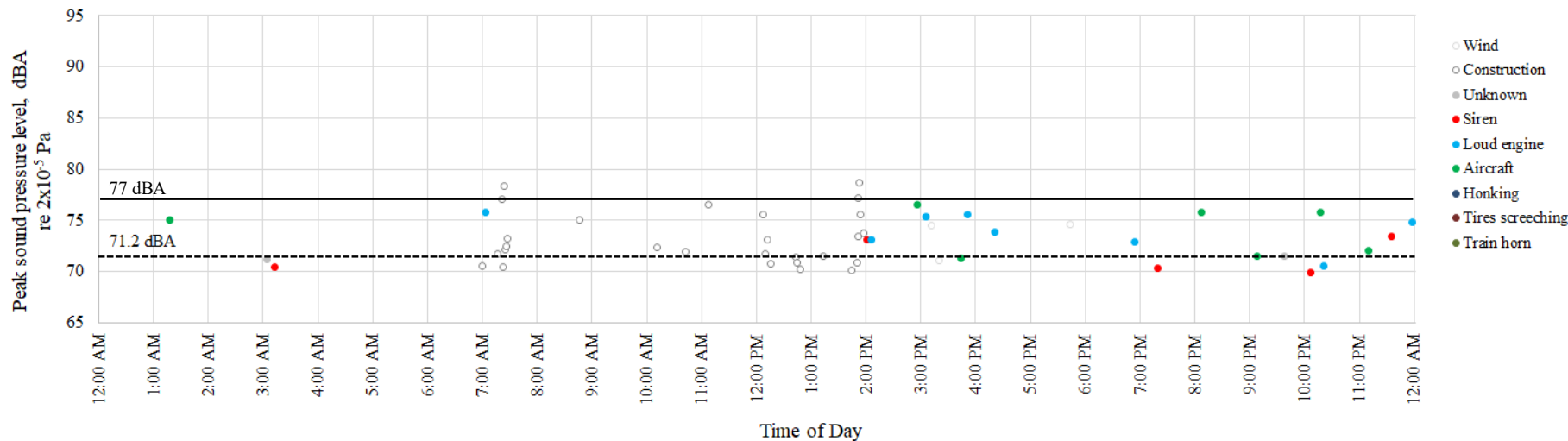


Figure B7 – Transient Noise Log for Tuesday, April 16, 2019

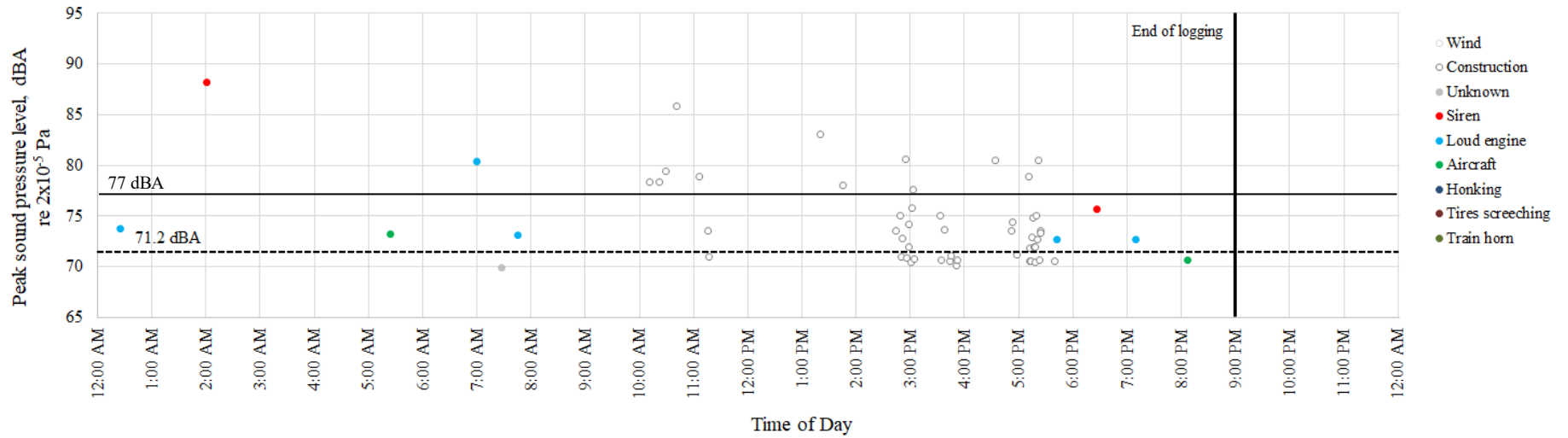


Figure B8 – Transient Noise Log for Wednesday, April 17, 2019

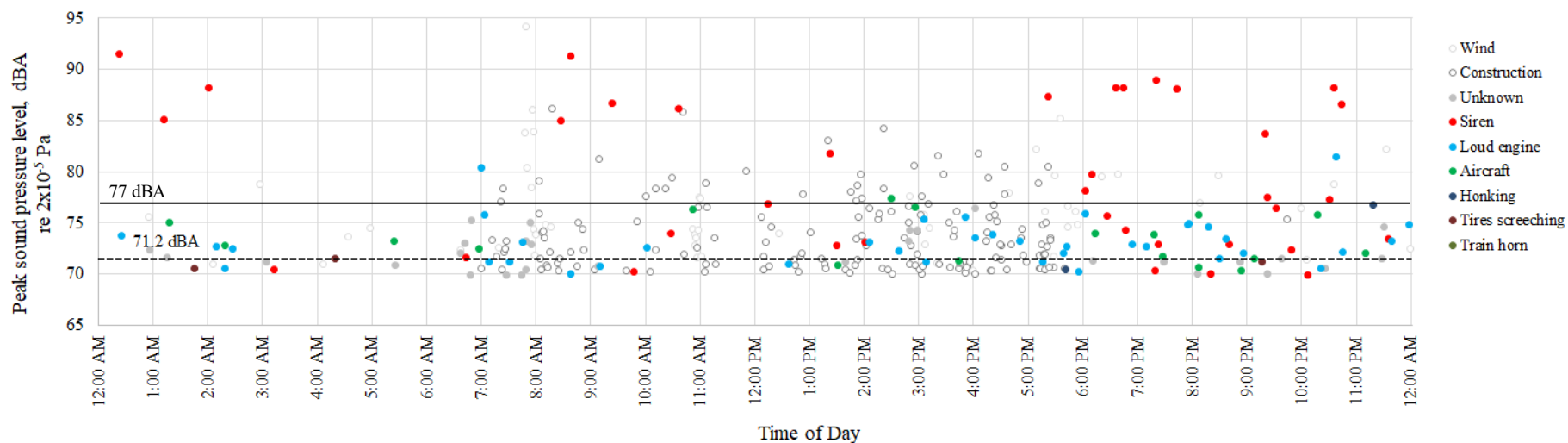


Figure B9 – Combined transient noise log for April 10 – April 17, 2019